

Bacteria contamination has declined but remains a problem in the Green/Duwamish River, Seattle, WA

Kate Macneale, Wendy Eash-Loucks and Dean Wilson • King County Water and Land Resources Division, Seattle, WA



Introduction

- Improvements to sewage conveyance and treatment in the last 40 years have improved water quality in many cities, but the discharge of untreated sewage and stormwater via combined sewer overflows (CSOs) during heavy rain events continues to be a source of contaminants, including bacteria.
- Additional sources of bacteria contamination can include wildlife, livestock, pets, poorly managed septic systems, and natural bacteria populations.
- WA State water quality standards for bacteria are based on fecal coliform concentrations, while the US Environmental Protection Agency (EPA) has recommended that *Enterococcus*, another type of bacteria, is a better indicator of human health risk. In either case, and high concentrations are often associated with untreated sewage.
- By comparing bacteria at sites upstream and within reaches affected by CSOs, we assess how CSOs and other potential sources of bacteria are influencing water quality of the river.

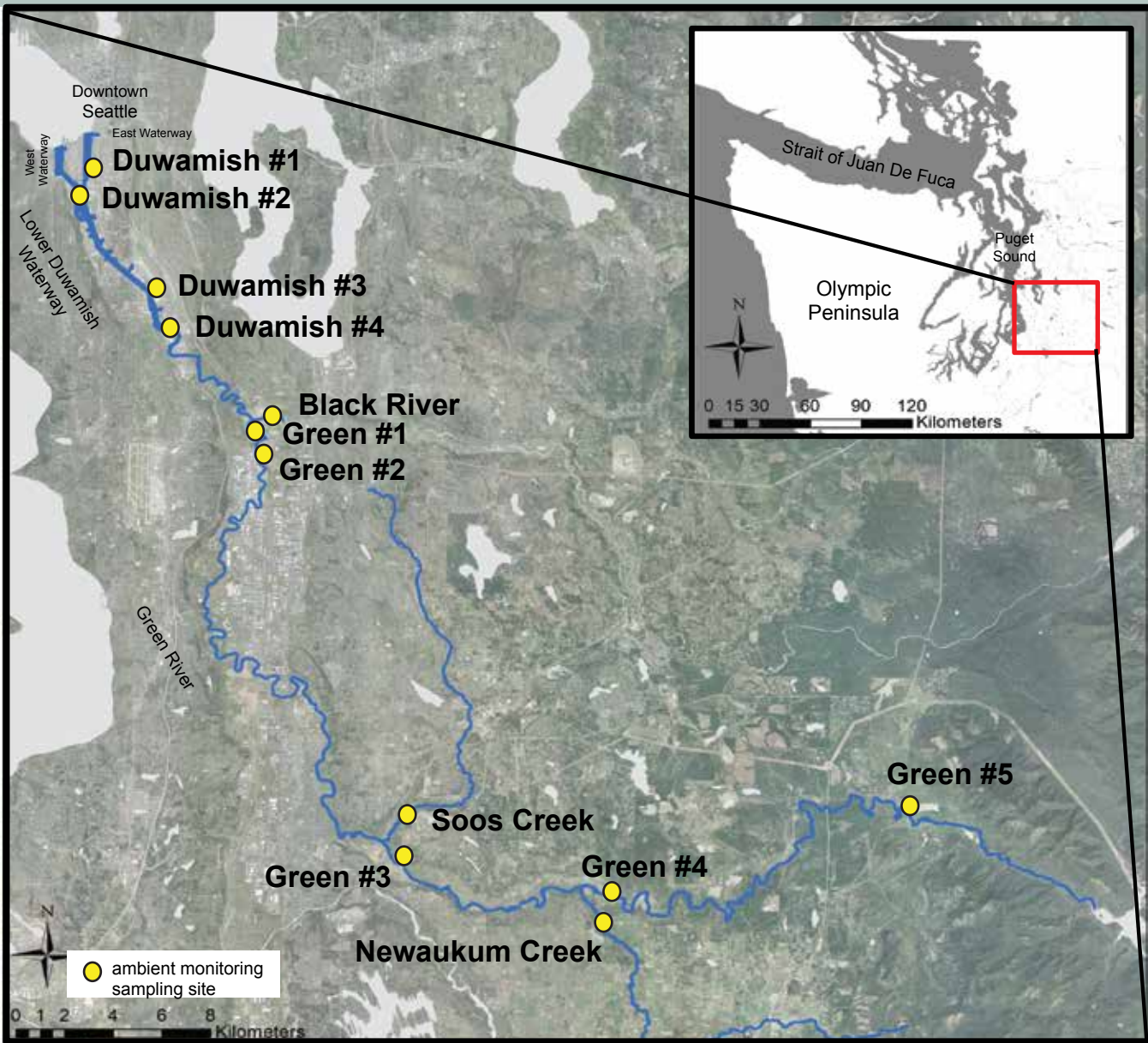


Figure 1. Ambient monitoring sites along the Green/Duwamish River, WA. Tributaries highlighted here include the Black River, Soos Creek and Newaukum Creek. Monitoring sites are noted with yellow circles.

Study Area

- The Green/Duwamish River flows through Seattle, WA (Fig. 1), and like many urban rivers, it has historically been affected by myriad sources of pollution.
- There are 18 CSOs within the lower river, as well as many stormwater outfalls (Fig. 4). There are additional stormwater outfalls upstream, in the Green River and in tributaries, but there are no CSOs upstream of the waterways.

Question 1: What are current bacteria concentrations in the river, and how have they changed over time?

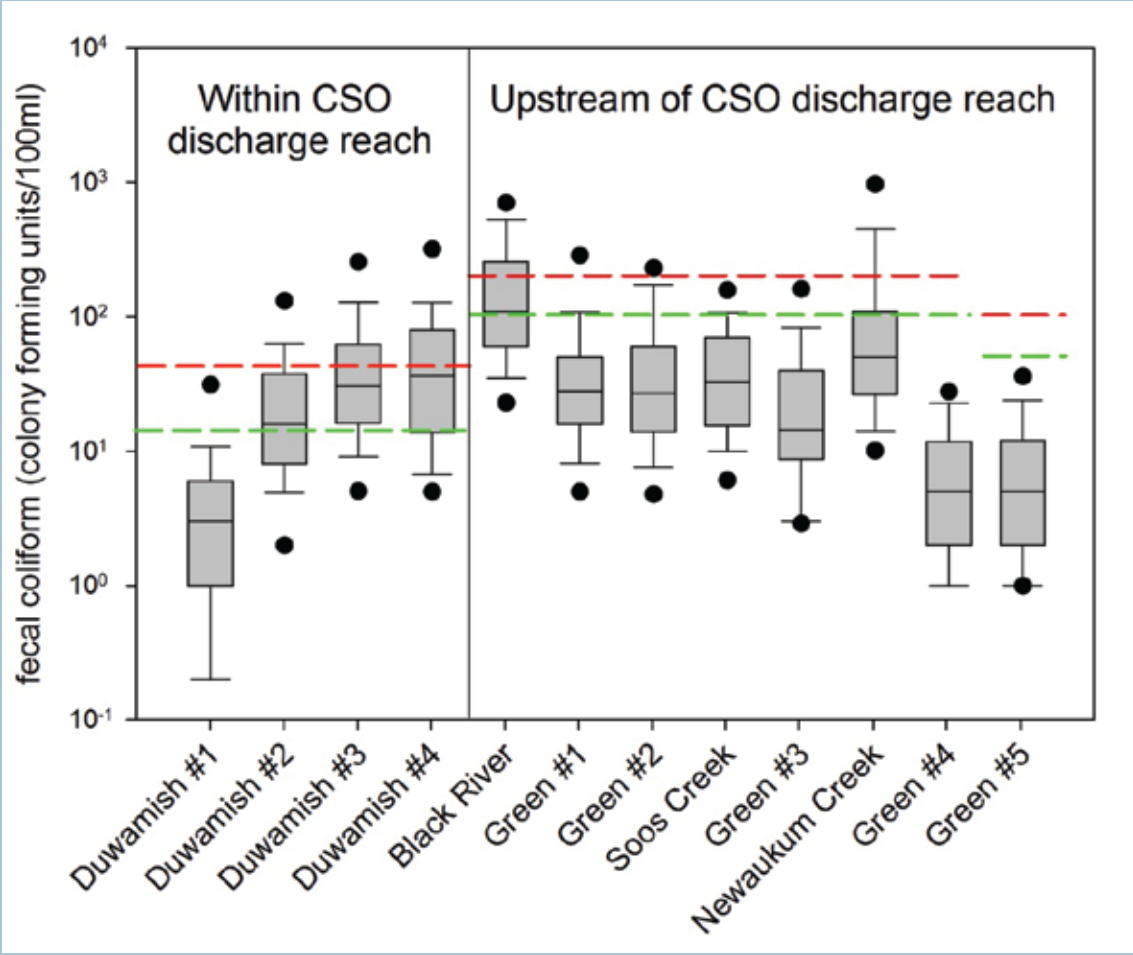


Figure 2. Fecal coliform concentrations in water from sites within and upstream of CSOs, sampled from 2004 - 2013. Box and whisker plots display the median and 10th, 25th, 75th, and 90th percentiles. Fifth and 95th percentiles are represented by dots. Peak standards (not to be exceeded in >10% of samples) are noted with the red dashed lines. Geomean standards are noted with green dashed lines.

Methods: Status and trends

- Fecal coliform data were analyzed from water samples collected monthly as part of King County's and the WA Department of Ecology's ambient monitoring programs.
- Samples were collected at 1 m depth at the four Duwamish sites, and ~15 cm below the surface at the eight upstream sites.
- Concentrations were compared to WA State water quality standards, which differ by reach depending on the human & aquatic use designations (see Figure 2).
- Trends were analyzed using Seasonal Mann-Kendall tests with precipitation included as a covariable.

Results: Fecal coliform status and trends

- Concentrations typically exceed water quality standards at three of the four sites within the reach with CSOs, and at two of the eight sites upstream.
- Concentrations tend to be highest in tributaries to the Green River.
- They are lowest near Elliott Bay, where tidal dilution and salinity likely affect concentrations and colony viability.
- There have been significant reductions over the last 34 years, in reaches with CSOs as well as upstream.
- The only site that has not had significant declines is Green #5. This suggests baseline fecal coliform concentrations in minimally disturbed portions of the watershed have been low and stable over time.

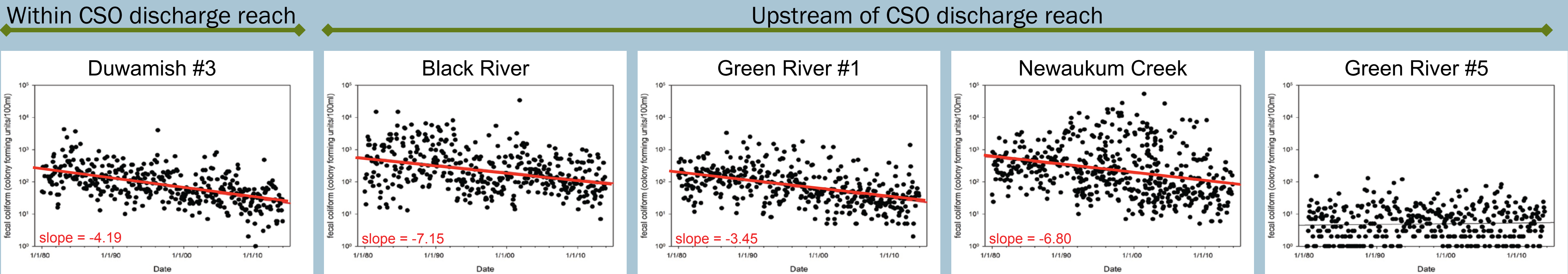


Figure 3. Monthly fecal coliform concentrations in water collected from 5 sites between January 1980 and December 2013. Red lines and slopes indicate significant negative trends over time.

Question 2: What does fine-scale sampling suggest about other potential sources of bacteria contamination?

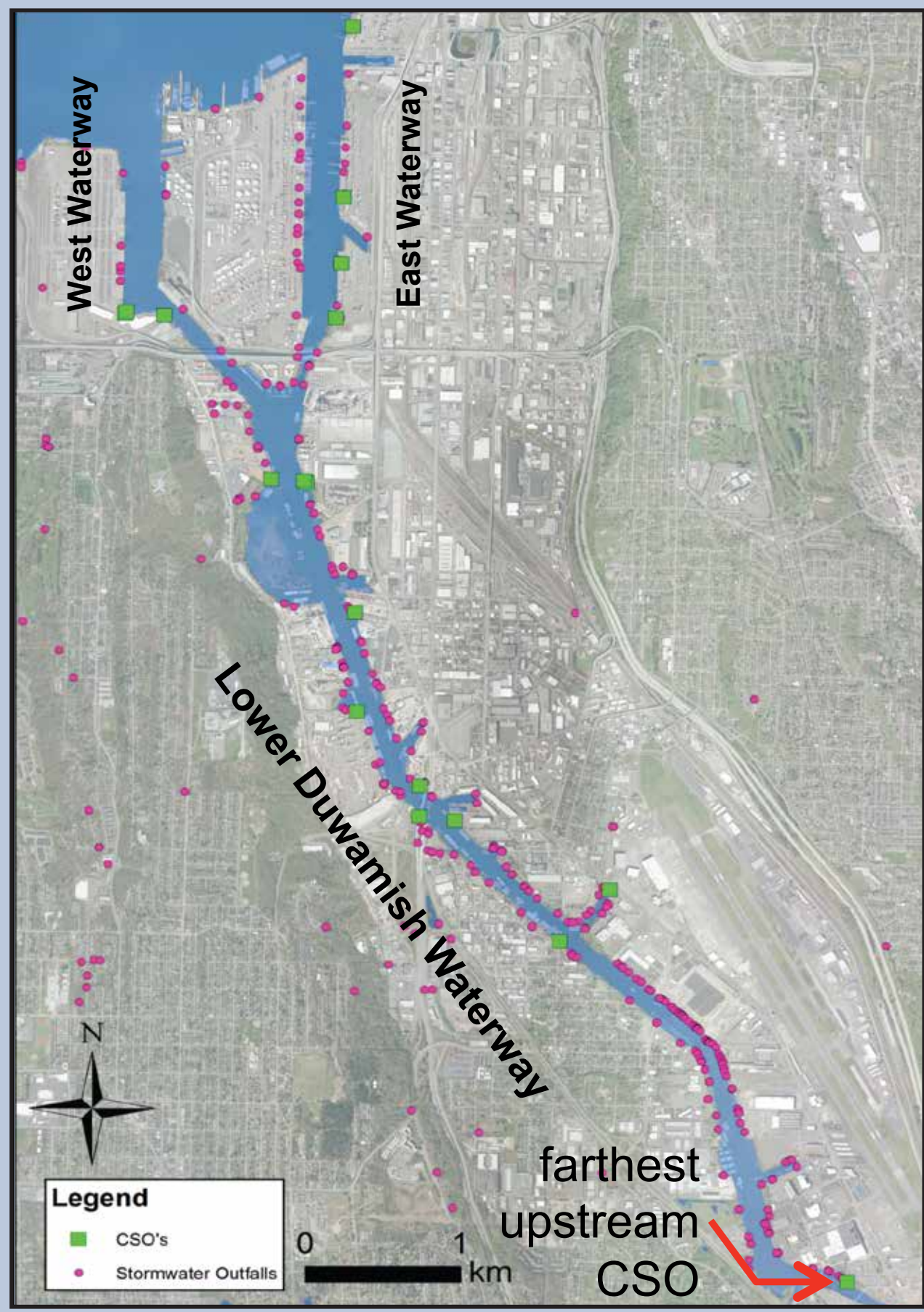


Figure 4. The East, West, and Lower Duwamish Waterways. CSOs are noted with green squares; stormwater outfalls are noted with pink circles.

Methods: Fine-scale bacteria sampling

- To assess the fine-scale distribution of bacteria, we analyzed *Enterococcus* from samples collected on two days in the winter of 2014.
- Samples were collected at 109 sites, each spaced 150 m from one another (Figures 5 and 6). Samples were collected ~15 cm below the surface.

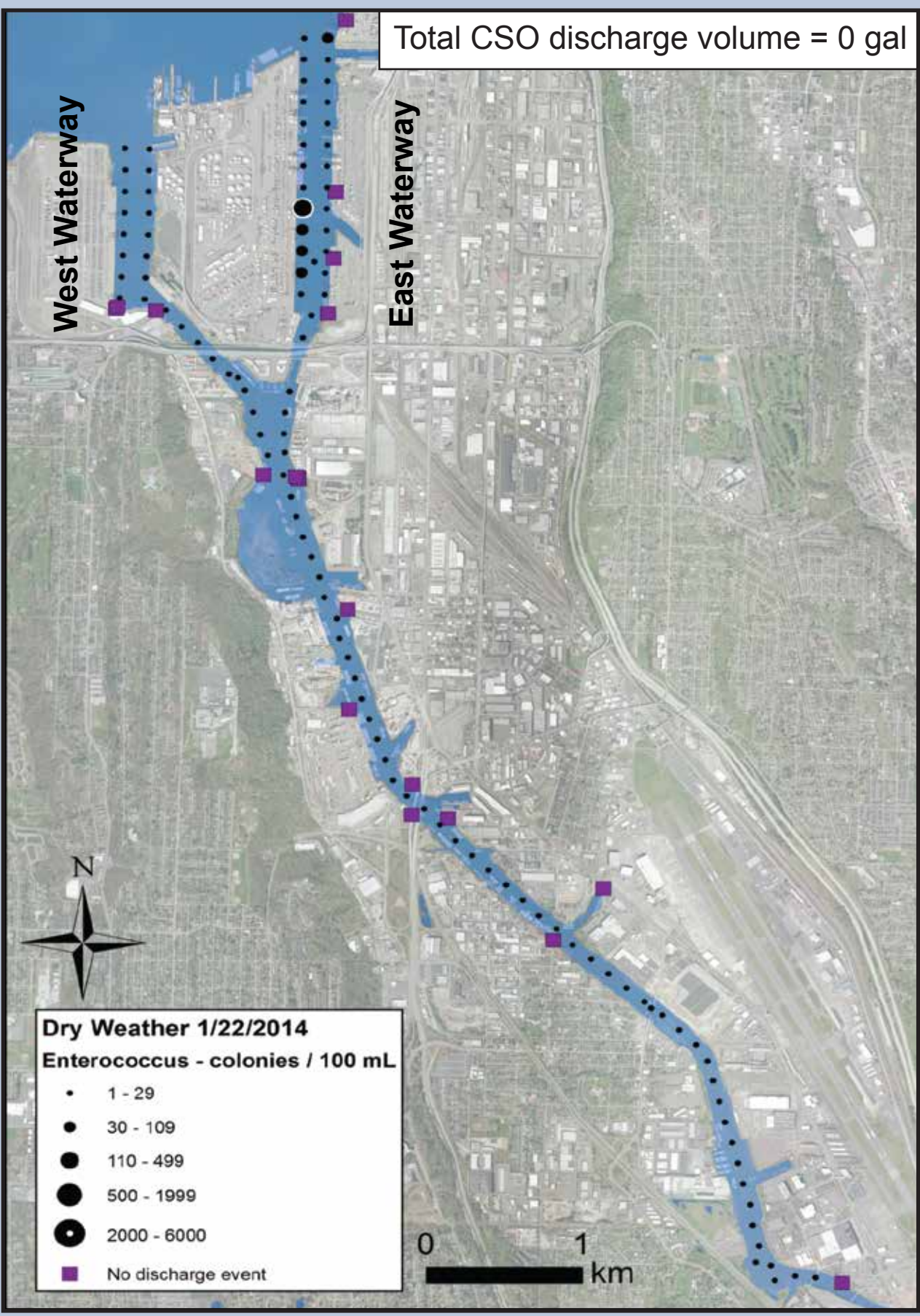


Figure 5. Enterococcus bacteria concentrations at sites sampled on January 22, 2014. No CSOs discharged and there had been no precipitation for over a week before sampling.

Results: Dry weather fine-scale bacteria sampling

- Enterococcus* were within EPA's criteria (geomean = 7.7 CFU/100ml, which is less than the standard of 30 CFU/100ml, and only 1% of samples exceeded peak standard of 110 CFU/100ml).
- Elevated concentrations in East Waterway suggest a source other than sewage.
- Concentrations in the rest of the river were low, indicating few dry-weather sources either within or upstream of the waterways.

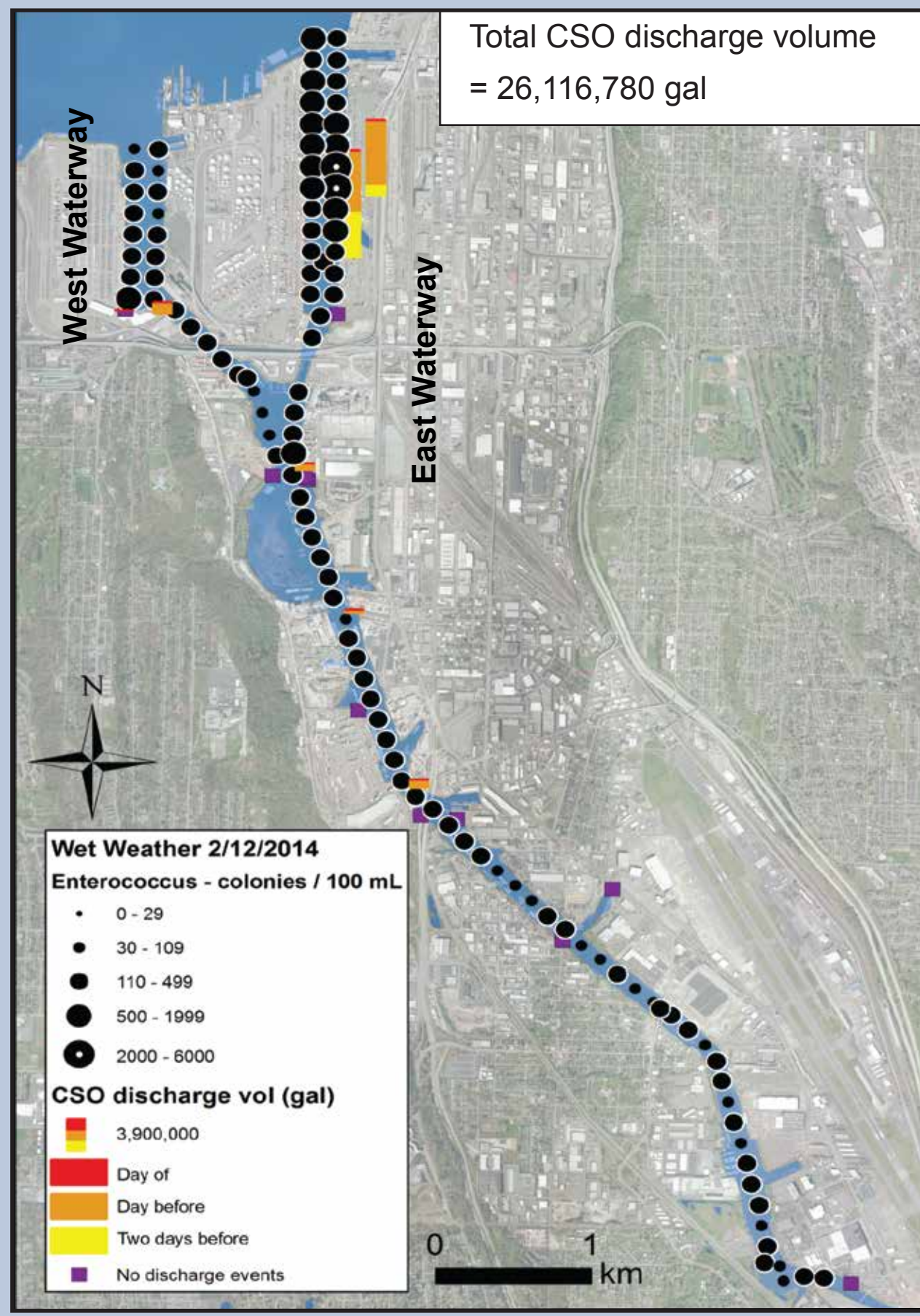


Figure 6. Enterococcus bacteria concentrations at sites on February 12, 2014. Seven CSOs discharged and ~2.5 cm of rain had fallen within two days of sampling. CSO discharge volumes are given in red, orange and yellow bars.

Results: Wet weather fine-scale bacteria sampling

- Enterococcus* exceeded EPA's criteria (geomean = 192.5 CFU/100ml, which is greater than the 30 CFU/100ml standard, and 81% of samples exceeded peak standard of 110 CFU/100ml).
- Highest concentrations were found at sites near two CSOs that collectively discharged over 23 million gallons of combined sewage and stormwater within three days of sampling.
- Concentrations at sites upstream of discharging CSOs were ~30 times higher in the wet- vs. the dry-weather sample, suggesting upstream, non-CSO sources of *Enterococcus*.

Conclusions

- Ambient monitoring data indicate fecal coliform concentrations vary widely along the river, with the highest concentrations in tributaries upstream of CSOs.
- Fecal coliform concentrations have declined at most sites over the last 34 years, although the rates of decline have been greatest at some sites upstream of CSOs.
- Further controls of CSOs will likely benefit ambient water quality in the lower portion of the river, but upstream sources may continue to be a source of bacteria contamination.
- Fine-scale sampling of bacteria may help to identify potential dry-weather sources of bacteria contamination, and may help to distinguish relative contributions of CSOs and upstream sources during storm events.

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For more information:

Kate.Macneale@kingcounty.gov